CLAIMS

What is claimed is:

1. A system for estimating frequency offset in an orthogonal frequency-division multiplexing (OFDM) system, comprising:

a sliding window correlation summing device that receives an input and generates a sliding window correlation sum in accordance with a reference symbol; and

a frequency offset estimator that is coupled to said sliding window correlation summing device and receives and processes said sliding window correlation sum to calculate a frequency offset estimation, wherein said reference symbol comprises an analytic tone located in only one subchannel of said reference symbol.

2. The system of claim 1, further comprising a timing offset estimator that receives said input and generates said timing offset estimation independent of said frequency offset estimation.

3. The system of claim 2, said timing offset estimator comprising:

a first delayer that delays said input in accordance with a first interval and a second interval, and generates a first delayed output;

a second delayer that is coupled to said first delayer and delays said first delayed output in accordance with said first interval to generate a second delayed output;

a conjugator that is coupled to said second delayer and performs a first operation on said second delayed output to generate a conjugated output;

a mixer that is coupled to said conjugator and said first delayer and mixes said conjugated output and said first delayed output to generate a mixer output;

a timing offset calculator coupled to said mixer and calculating a plurality of timing offset estimations in response to said mixer output; and

a maximum value detector that is coupled to said timing offset calculator, detects a maximum value of said plurality of timing offset calculations from said timing offset calculator, and outputs said timing offset estimation.

4. The system of claim 3, wherein said first interval and said second interval have different values, said first interval is a timing offset estimation interval and said second interval is a frequency offset estimation interval.

5. The system of claim 3, wherein said timing offset calculator calculates said plurality of timing offset estimations for (N+G-a1) samples, wherein N represents a total number of subcarriers, G represents a guard interval length, and a1 represents a timing offset estimation interval.

6. The system of claim 3, wherein said timing offset estimation is calculated by selecting a maximum value for the samples for which a second operation comprising ($\sum_{i=0}^{N+G-a-1} R_{n+1,a}^{(z)}$) is performed by said timing offset calculator for each of said samples.

7. The system of claim 1, said sliding window correlation sum comprising:

a first delayer that delays said input signal in accordance with a frequency offset estimation interval to generate a first delayed output;

a conjugator that performs a first operation on said first delayed output to generate a conjugated output; and

a mixer that mixes said conjugated output and said input signal to generate a mixer output.

8. The system of claim 7, wherein (N-a2) samples are generated in a moving sum in accordance with said mixer output, and N represents a total number of subcarriers and a2 represents a frequency offset estimation interval.

9. The system of claim 1, said frequency offset estimator comprising:

an analytic tone-phase compensation device that receives said sliding window correlation sum and performs a phase compensation operation to a generate a phase-compensated output; and

a frequency offset estimation calculator coupled to said analytic tone-phase compensation device and receiving said phase-compensated output and calculates said frequency offset estimation.

10. The system of claim 9, said frequency offset estimation calculator comprising:

a first calculator that performs a first operation to generate a first calculated output; and

a second calculator that receives said first calculated output and generates said frequency offset estimation.

11. The system of claim 10, wherein said first operation comprises calculating $\tan^{-1}[e^{-ja\phi_b} \cdot \sum_{i=0}^{n-a-1} R^{(z)}_{\wedge+c+i,a}]$ and said frequency offset estimation comprises multiplying said first calculated output by $N/2\pi a$, wherein N is a number of total subcarriers and a is a number of samples.

12. The system of claim 1, further comprising a switch that outputs said frequency offset estimation in accordance with said timing offset estimation.

13. The system of claim 1, wherein an estimation range of said system can be extended by adjusting a correlation interval between samples.

14. The system of claim 1, wherein said analytic tone has at least one of a uniform magnitude and a uniform phase rotation, and no coarse synchronization is required.

15. The system of claim 1, wherein said frequency offset estimation is less than or equal to (N/2a), wherein N represents a number of subcarriers and a represents a number of samples.

16. The system of claim 15, wherein a maximum estimation range of the estimation is determined in accordance with said number of samples.

17. The system of claim 16, wherein said maximum estimation range is ±32 subcarrier spacing when N has a value equal to 1.

18. A system for estimating frequency offset in an orthogonal frequency-division multiplexing (OFDM) system, comprising:

a sliding window correlation summing device that receives an input and generates a sliding window correlation sum in accordance with a symbol;

a frequency offset estimator coupled to said sliding window correlation summing device and receiving said sliding window correlation sum and calculates a frequency offset estimation in accordance with a timing offset estimation, said frequency offset estimator comprising,

an analytic tone-phase compensation device that receives said sliding window correlation sum and performs a phase compensation operation to a generate a phase-compensated output, and

a frequency offset estimation calculator that receives that said phase-compensation output and calculates said frequency offset estimation, wherein an analytic tone is used in a correlation function; and

a timing offset estimator that receives said input signal and generates said timing offset estimation independent of said frequency offset estimation, wherein an estimation range can be extended by adjusting a correlation interval between samples, said analytic tone has at least one of a uniform magnitude and a uniform phase rotation, and no coarse synchronization is required.

19. A system for estimating frequency offset in an orthogonal frequency-division multiplexing (OFDM) system, comprising:

a sliding window correlation summing device that receives an input and generates a sliding window correlation sum in accordance with a reference symbol; and

a frequency offset estimator that is coupled to said sliding window correlation summing device and receives said sliding window correlation sum to calculate a frequency offset estimation, wherein an analytic tone is used in a correlation function.

20. The system of claim 19, further comprising a timing offset estimator that receives said input and generates said timing offset estimation independent of said frequency offset estimation, comprising:

a first delayer that delays said input in accordance with a first interval and a second interval to generate a first delayed output;

a second delayer coupled to said first delayer and delaying said first delayed output in accordance with said first interval to generate a second delayed output;

a conjugator coupled to said second delayer and performing a calculation on said second delayed output to generate a conjugated output;

a mixer coupled to said conjugator and said first delayer and adding said conjugated output and said first delayed output to generate a sum;

a timing offset calculator coupled to said mixer and calculating a plurality of timing offset estimations in response to said sum; and

a maximum value detector coupled to said timing offset calculator and selecting a maximum value from said plurality of timing offset estimators to output said timing offset estimation.

21. A method for frequency offset estimation, comprising the steps of:

(a) detecting an analytic tone located on only one subcarrier of a reference symbol of an input signal;

(b) generating a sliding window correlation sum in accordance with said analytic tone; and

(c) calculating a frequency offset estimation of said sliding window correlation sum.

22. The method of claim 21, wherein a further step of generating said timing offset estimation independently of said frequency offset estimation comprises:

(a) delaying said input signal in accordance with a first interval and a second interval to generate a first delayed output;

(b) delaying said first delayed output in accordance with said first interval to generate a second delayed output;

(c) performing an operation on said second delayed output to generate a conjugated output;

(d) mixing said conjugated output and said first delayed output to generate a mixed output;

(e) producing a plurality of timing offset estimations for a corresponding plurality of samples in response to said mixed output; and

(f) detecting a maximum value of said plurality of timing offset calculations to output said timing offset estimation.

23. The method of claim 22, further comprising:

(a) generating said first interval as a timing estimation interval; and

(b) generating said second interval as a frequency offset estimation interval.

24. The method of claim 22, said producing step comprising producing said plurality of timing offset estimations for (N+G-a1) samples, wherein N represents a total number of subcarriers, G represents a guard interval length, and a1 represents a timing offset estimation interval.

25. The method of claim 22, wherein said detecting step comprises selecting a maximum value for the samples for which said producing step comprises performing an operation comprising ($\sum_{i=0}^{N+G-a-1} R_{n+1,a}^{(z)}$) on each of said samples.

26. The method of claim 25, said step (b) comprising:

delaying said input signal in accordance with a frequency offset interval to generate a first delayed output;

performing an operation on said first delayed output to generate a conjugated output; and

mixing said conjugated output and said input signal to generate a mixed output.

27. The method of claim 26, comprising generating (N-a2) samples in a moving sum in accordance with said mixed output, wherein N represents a total number of subcarriers and a2 represents a frequency offset estimation interval.

28. The method of claim 21, said calculating step comprising:

performing a phase compensation operation on said sliding window correlation sum to generate a phase-compensated output; and

receiving said phase-compensated output and calculating said frequency offset estimation.

29. The method of claim 21, said calculating step comprising:

performing an operation to generate a calculated output; and

receiving said calculated output and generating said frequency offset estimation.

30. The method of claim 29, wherein performing said operation comprises calculating $\tan^{-1}[e^{-ja\phi_b} \cdot \sum_{i=0}^{n-a-1} R^{(z)}_{\wedge+c+i,a}]$ and estimating said frequency offset comprises multiplying said first calculated output by $N/2\pi a$, wherein N is a number of total subcarriers and a is a number of samples.

31. The method of claim 21, further comprising extending an estimation range by adjusting a correlation interval between samples.

32. The method of claim 21, wherein said analytic tone is generated to have at least one of a uniform magnitude and a uniform phase rotation.

33. The method of claim 21, wherein said frequency offset estimation is less than or equal to (N/2a), wherein N represents a number of subcarriers and a represents a number of samples.

34. The method of claim 21, further comprising changing a maximum estimation range of the estimation in accordance with said number of samples.

35. The method of claim 34, wherein said maximum estimation range is ±32 subcarrier spacing when N equals a value of 1.

36. A method for frequency offset estimation, comprising the steps of:

(a) detecting an analytic tone located on only one subcarrier of a reference symbol of an input signal;

(b) generating a sliding window correlation sum in accordance with said analytic tone, said step (b) comprising,

delaying said input in accordance with a frequency offset interval to generate a first delayed output,

performing an operation on said first delayed output to generate a conjugated output, and

mixing said conjugated output and said input signal to generate a mixed output; and

(c) calculating a frequency offset estimation of said sliding window correlation sum in accordance with a timing offset estimation, said calculating step comprising,

(a) performing a phase compensation operation on said sliding window correlation sum to generate a phase-compensated output,

(b) performing a first mathematical operation to generate a first calculated output, and

(c) receiving said first calculated output and generating said frequency offset estimation; and

(d) extending an estimation range by adjusting a correlation interval between samples, wherein a correlation interval is adjusted such that no coarse tuning is required.

37. The method of claim 36, wherein a further step of generating said timing offset estimation independently of said frequency offset estimation comprises

(a) delaying said input signal in accordance with a timing estimation interval and a frequency offset estimation interval to generate a first delayed output;

(b) delaying said first delayed output in accordance with said timing estimation interval to generate a second delayed output;

(c) performing a calculation on said second delayed output to generate a conjugated output;

(d) adding said conjugated output and said first delayed output to generate a sum;

(e) calculating a plurality of timing offset estimations on a corresponding plurality of samples in a timing offset calculator and in response to said sum; and

(f) detecting a maximum value of said plurality of timing offset calculations from said timing offset calculator to output said timing offset estimation, wherein said detecting step comprises selecting a maximum value for the samples for which said calculating step comprises performing a mathematical operation comprising ($\sum_{i=0}^{N+G-a-1} R^{(z)}_{n+1,a}$) on each of said samples, and said frequency offset estimator is output in accordance with said timing offset estimation.

38. The method of claim 37, wherein performing said operation comprises calculating $\tan^{-1}[e^{-ja\phi_b} \cdot \sum_{i=0}^{n-a-1} R^{(z)}_{\wedge+c+i,a}]$, and estimating said frequency offset comprises multiplying said first calculated output by N/2πa, wherein N is a number of total subcarriers and a is a number of samples.

39. The method of claim 36, wherein said analytic tone is generated to have at least one of a uniform magnitude and a uniform phase rotation.

40. A method for frequency offset estimation, comprising the steps of:

(a) detecting an analytic tone of an input signal wherein said analytic tone has at least one of a uniform magnitude and a uniform phase rotation;

(b) generating a sliding window correlation sum in accordance with said analytic tone; and

(c) calculating a frequency offset estimation of said sliding window correlation.